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COMPARATIVE HISTOLOGICAL STUDY OF THE REINFORCED AREA OF THE SACCULAR MEMBRANE IN MAMMALS

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JOINT REPORT

UNITED STATES NAVAL SCHOOL OF AVIATION MEDICINE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Research Report

COMPARATIVE HISTOLOGICAL STUDY OF THE REINFORCED AREA OF THE SACCULAR MEMBRANE IN MAMMALS*

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Bureau of Medicine and Surgery
Project MR005.13-6001
Subtask 1 Report No. 101

NASA Order No. R-93

Approved by

Captain Ashton Graybiel, MC USN
Director of Research

Released by

Captain H. C. Hunley, MC USN
Commanding Officer

14 October 1964

*This research was conducted under the sponsorship of the Office of Life Science Programs, National Aeronautics and Space Administration.

U. S. NAVAL SCHOOL OF AVIATION MEDICINE
U. S. NAVAL AVIATION MEDICAL CENTER
PENSACOLA, FLORIDA

SUMMARY PAGE

THE PROBLEM

The reinforced area of the saccular membrane is probably a structure protecting the macular end organ. An attempt has been made to investigate and compare this structure microscopically in 65 mammalian inner ears, including those of man.

FINDINGS

A definite reinforced area of the saccular membrane existed in all of the human ears examined. Its existence was also demonstrated in all of the squirrel monkey ears studied; however, some of these showed narrow or questionable formations. The ears of all the four-legged mammals investigated, on the other hand, showed no reinforced area except those of the flying squirrel. It is possible that, as a stimulus receptor, the function of the saccule in primates differs from that of the saccule in lower mammals.

ACKNOWLEDGMENT

Grateful appreciation is expressed to Captain Ashton Graybiel, MC, USN, for his warm support.

INTRODUCTION

The reinforced structure at the anterior part of the saccular membrane was first described by Perlman in 1940 (4), and he termed it a "differentiated reenforced area of the saccular wall." Because of the presence of this area in man and its absence in the lower mammalian forms he examined, Perlman suggested that the saccule in man may have a function different from that in lower mammalian forms. In other words, the experimental findings in these lower forms of an acoustic function for the saccule indicated to him that these findings might not hold for man or the monkey Macacus rhesus. Also, Perlman stated it would be more reasonable to expect that "this differentiated area of saccular wall in man has a functional significance and that it does not represent merely a support for a few extremely small blood vessels." These anatomical findings were later confirmed by Bast and Anson (1).

The present study is an extension of those previous ones but differs in that it is concerned primarily with a lower primate. Because the squirrel monkey is used extensively in the study of vestibular function, a comparative histological investigation was performed using mainly the Saimiri sciureus, a species of South American monkeys which is a definitely lower one than the Macacus rhesus, an Old World monkey.

MATERIAL AND METHODS

A total of 65 temporal bones were examined. These consisted of 36 squirrel monkey ears, 10 human ones, 7 ears from cats, 4 from guinea pigs and from rats, and two ears from dogs and from flying squirrels.

All temporal bones were fixed (most of the animals were intravitally perfused), decalcified, neutralized, dehydrated, embedded in celloidin, and serially sectioned in horizontal plane at 20 microns. One of each ten sections was stained in hematoxylin-eosin or hematoxylin-phloxine and investigated microscopically.

RESULTS AND DISCUSSION

As can be seen from Table I, which summarizes the findings, all 10 human ears showed an evident reinforced area at the anterior one third of the saccular membrane. This reinforcement was an extension of the connective tissue between two epithelial cell layers from the anterior margin of the saccular membrane (Figures 1,2). Small blood vessels were sometimes observed in this area, especially in young and in fetal inner ears.

This reinforced area is quite probably a protective structure. It may be protecting the saccular end organ from excessive or intensive perilymphatic displacement, especially from the anterior edge of the footplate. More extensive displacement of the footplate is suspected at that point from the anatomical features of the annural ligament and stapedial tendon. When rupture of the saccular membrane, either pre or post mortem, is observed in human temporal bones, it is not in the reinforced area (Figure 3).

Table I

Incidence with which a Reinforced Area of the Saccular Membrane Was Found in 65 Mammalian Ears

Animal	Number of Ears	Reinforced Area: Evident	Reinforced Area: Short, Narrow, or Thin	Reinforced Area: Questionable	Reinforced Area: Negative
Human	10	10	0	0	0
Squirrel monkey	36	13	19	4	0
Cat	7	0	0	0	7
Dog	2	0	0	0	2
Guinea pig	4	0	0	0	4
Rat	4	0	0	0	4
Flying squirrel	2	2	0	0	0

Microphotographs representative of the findings in the squirrel monkey ears (Table I) are seen in Figures 4-8. An additional observation in a rhesus monkey ear (not part of the present study) confirmed Perlman's finding (4) of a well-defined area in this particular species. A questionable reinforcement of the saccular membrane in the squirrel monkey which was found in 4 of the 36 ears examined may be due to an Infra-order difference in the animal kingdom.

South American monkeys, such as the Saimiri sciureus, belong to the Infraorder Platyrrhini and are distinguishable by the lateral opening of their nostrils. Old World monkeys, such as Macacus rhesus, apes, and men, belong to the definitely higher Infra-order Catarrhini with the nostrils opening downward. The biological classification of experimental animals, especially in functional researches, should be submitted for more careful consideration.

The ears of the two-legged mammals investigated, which have unstable head positioning against the gravitoinertial forces, as a rule contained the reinforced area.

Of the ears from four-legged animals that were examined, only those of the flying squirrel showed a reinforced area (Figure 9). It is interesting to recognize that this animal makes very sudden stop and start movements, both horizontally and vertically, as well as a gliding movement. The negative reinforcement of the saccular membrane in cat ears (Figure 10A,B) is typical of that seen in the other four-legged animals.

After Perlman's suggestion (4) of an acoustic function for the saccule in lower animals, McCabe and Lawrence (3) found saccular lesions along with cochlear lesions in guinea pig ears after extensive acoustic stimulation. The noise levels used were 150 db and 136 db above 0.0002 dyne/cm^2 level, for twenty minutes, and the saccular or otolithic membrane lesions were observed in 23 out of 26 animals. In each case the other vestibular labyrinth remained intact. The saccule seemed definitely the vestibular locus minosus. Also, the degree of the saccular damage was parallel to the cochlear damage.

A cat that had been exposed to exceptionally severe and repeated head blows was reported by Schuknecht and Davidson (8) to have had saccular collapse. The remaining nine cats studied, but not exposed to the same head blows, showed no vestibular end organ damage at all.

No saccular lesion was observed in three human cases of stimulation deafness reported by Igarashi, Schuknecht, and Myers (2). Two of the individuals had histories of exposure for long periods of time to extremely high intensity noise (well over 120 db re 0.0002 dyne/cm^2), such as that caused by riveting machines in small compartments and boilers of ships. The other person had a history of severe head trauma from falling down a flight of stairs. The severity of the stimulation might differ between humans and experimental animals, but the difference among the different species cannot be neglected since, in man, cochleo-saccular degeneration has been observed after inner ear infection, in congenital malformation, and presbyacousis (6,7).

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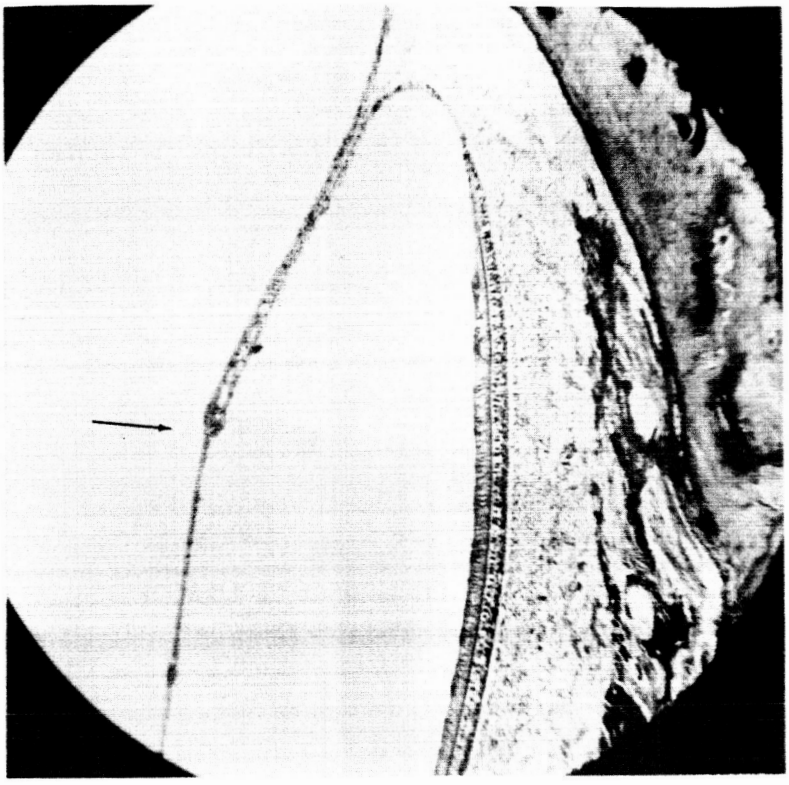

Figure 1

Showing the reinforced area at the anterior part of the saccular membrane. Human adult. All black arrows, appearing in this figure and subsequent microphotographs, indicate the posterior end of the reinforced area. 70 x

Figure 2

Showing rather thin reinforced areas from another human adult ear.
70 x

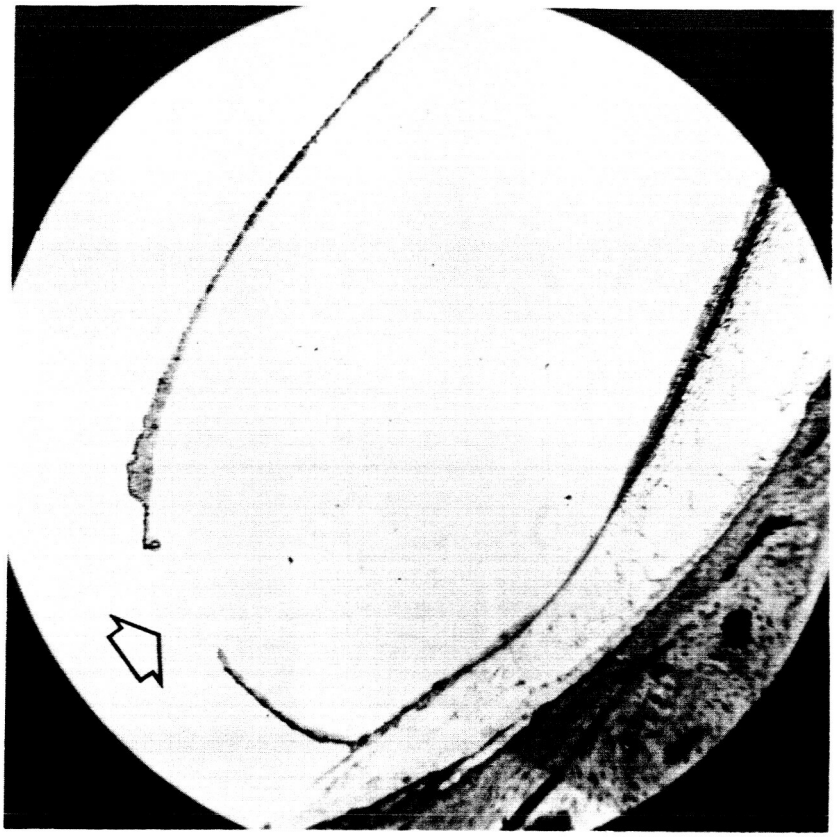

Figure 3

Demonstrating the rupture of saccular membrane which usually occurs at the posterior part (broad white arrow). Human adult. The rupturing edge usually curls up. 70 x

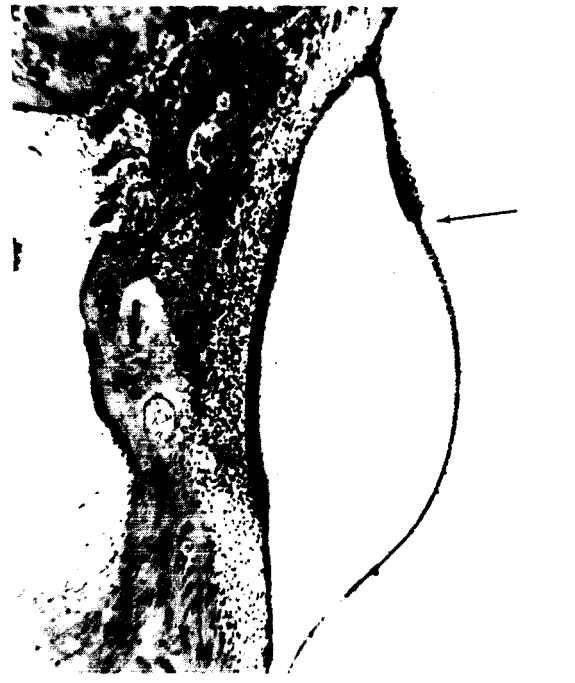

Figure 4

Showing a relatively thick reinforced area in a squirrel monkey. Otolithic membrane preservation is good in this case. 80 x

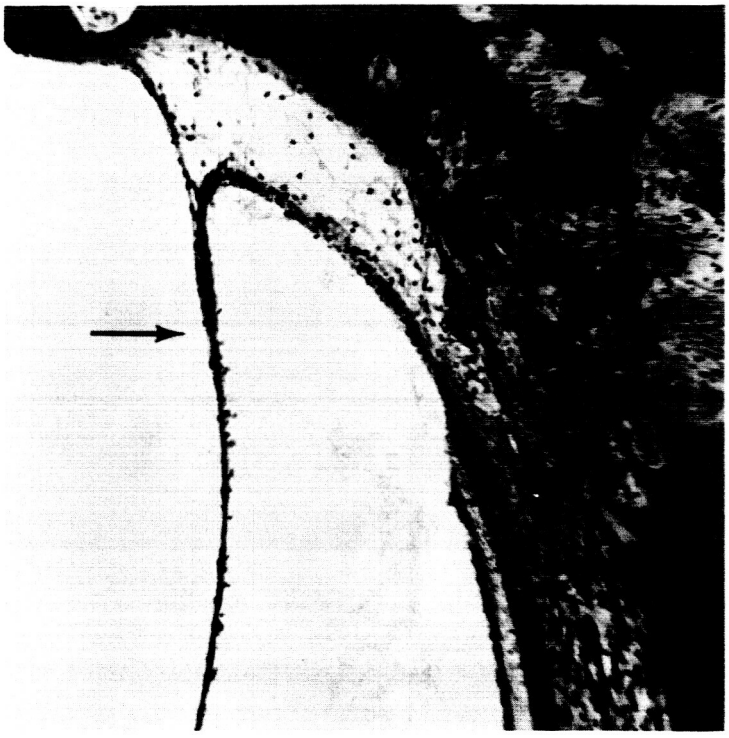

Figure 5

Showing a fairly thick, but narrow reinforced area in another squirrel monkey. 130 x

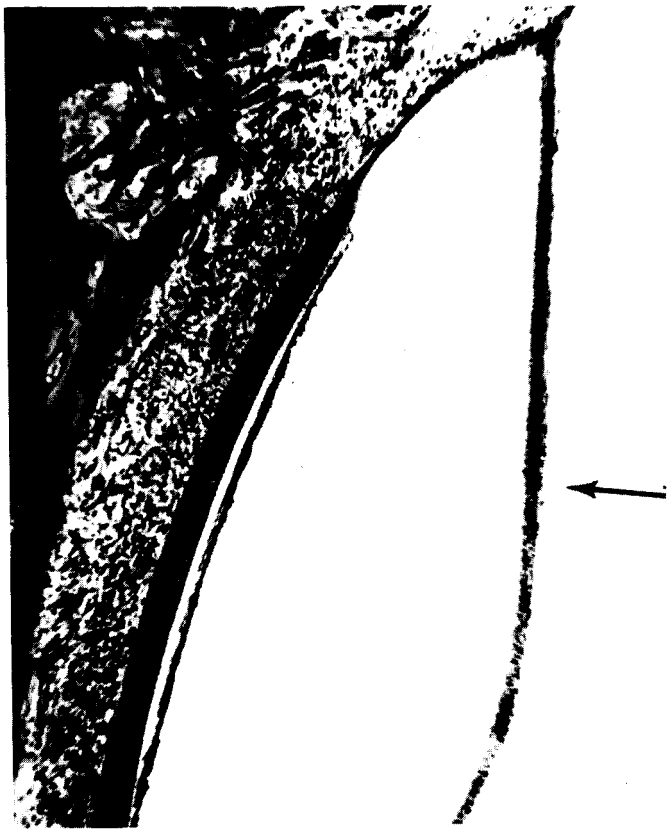

Figure 6

Shows a wide, but thin, reinforced area in a squirrel monkey. Normal saccular macula and otolithic membrane. 80 x

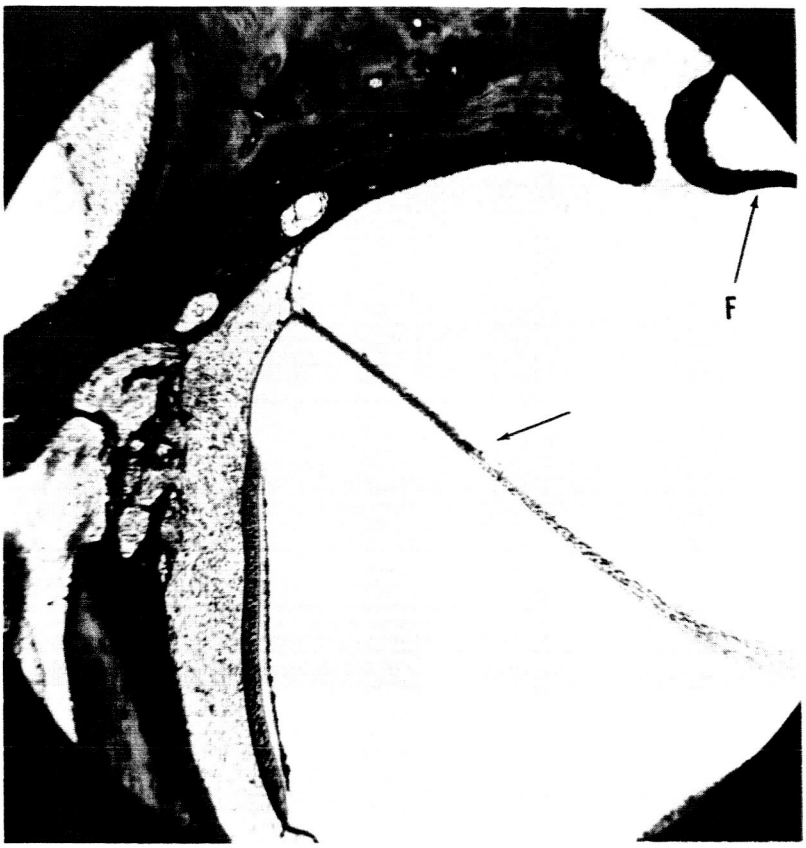

Figure 7

Another thin reinforced area in a squirrel monkey. Normal saccular macula and otolithic membrane. Note the saccular nerve goes through the bony lamina rather anteriorly to the saccular macula, and turns posteriorly. 80 x

F: Footplate of the stapes

Figure 8

Very narrow and questionable reinforcement of the saccular membrane in a squirrel monkey. Saccular end organ is normal. 80 x
V: Utriculo-endolymphatic valve (or fold)

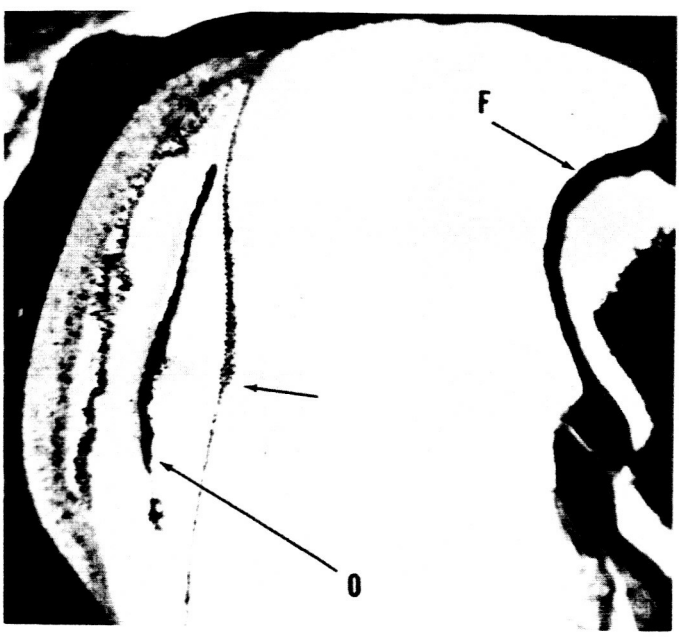

Figure 9

Demonstrating the reinforced area in a flying squirrel. The saccular macula is severely damaged from post-mortem degeneration and otolith membrane is dislocated. 70 x

F: Concave footplate of the stapes

O: Otolithic membrane

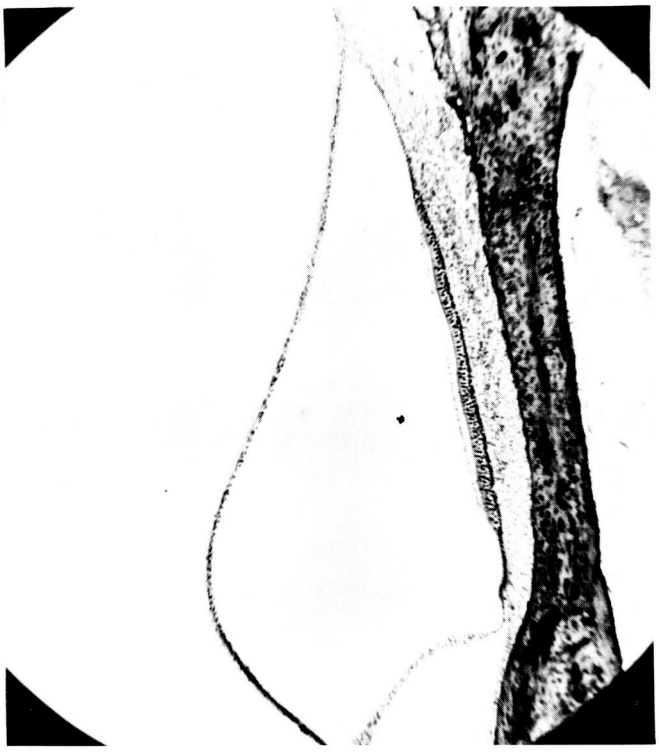

Figure 10 A

Figure 10 B

Figure 10

A and B: Negative reinforcement of the saccular membrane in a cat. Normal saccular end organ. 10A - 80 x
Fig. 10 B is a high power view of Fig. 10 A. 150 x